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VII. *An Account of the Extraordinary METEOR
seen all over England, on the 19th of March
171 $\frac{8}{9}$. With a Demonstration of the uncommon
Height thereof. By Edm. Halley, LL. D. and
Secretary to the Royal Society.*

HIIS wonderful luminous *Meteor* which was seen in the Heavens on the 19th of March last, as it was matter of Surprize and Astonishment to the Vulgar Spectator, so it afforded no less Subject of Enquiry and Entertainment to the speculative and curious in Physical things: Some of its *Phanomena* being exceeding hard to account for, according to the Notions hitherto received by our Naturalists; such are the very great Height thereof above the Earth; the vast Quantity of the Matter thereof; the extravagant Velocity wherewith it moved; and the prodigious Explosions thereof heard at so great a Distance, whose Sound, attended with a very sensible Tremour of the subject Air, was certainly propagated through a *Medium* incredibly rare and next to a *Vacuum*.

In Num. 341. of these *Transactions*, I have collected what I could find of such-like *Meteors*, and since, turning over the *Ephemerides* of *Kepler*, I accidentally hit upon another, prior to all those there described, and which was seen all over *Germany*. Of this the Words of *Kepler* are: *Die 7. Nov. 1623. Meteorum ignitum, Globus ardens ab occasu in ortum volans totâ passim Germaniâ fuit conspectus. In Austria etiam fragorem exauditum affirmarunt quasi à fulmine; quod vanum tamen puto: nihil enim tale confirmant descriptiones quæ extant.* Yet

neither this, nor any of the other hitherto described, seem to come up in any Circumstance to this late Appearance; of which I am in hopes to give a satisfactory Account, being enabled by the very many Relations thereof communicated to the *Royal Society*, from most parts of the Kingdom; tho' it was not my good Fortune to see it my self; and tho' very few of our Countrymen who best know the *Stars*, had better luck. Some of the most perfect Descriptions we have receiv'd are the following:

First, Our very worthy Vice-President Sir *Hans Sloan*, Baronet, being abroad at that time, happen'd to have his Eyes turned towards it, in its very first Eruption; and the next Day he was pleased to give me in Writing what he had with great Exactness noted about it, in the Terms following: " On Thursday, March 19. 17¹⁹. " passing along Eastward by the N E. Corner of *Sou-*
thampton-street in Bloomsbury-Square, London, at about
" a Quarter after Eight at Night, I was surpriz'd to
" see a sudden great Light, much beyond that of the
" Moon, which shone then very bright. I turn'd to
" the Westward where the Light was; which I appre-
" hended at first to be artificial Fire-works or Rockets.
" The first place i observ'd it in, was about the *Flet-*
ades Northerly, whence it moved after the manner,
" but more slowly than a falling Star, in a seeming
" direct Line, deicending a little beyond, and withal
" below, the Stars in *Orion's Belt* then in the S. W.
" The long Stream appear'd to me to be branched about
" the middle, and the *Meteor* in its way turn'd Pear-
" fashion'd or tapering upwards. At the lower end it
" came at last to be bigger and Spherical, tho' it was
" not so big as the Full Moon. The Colour of it was
" whitish, with an eye of Blue, of a most vivid daz-
" ling Lustre, which seem'd in Brightness very nearly

" to resemble, if not surpass that of the Body of the
 " Sun in a clear Day, beheld by the naked Eye This
 " Brightness obliged me to turn my Eyes (which had
 " their Pupils adapted to the Light of the Moon) from
 " it several times, as well when it was a Stream, as
 " when it was Pear-fashion'd and a Globe: tho' I had
 " a great Curiosity to observe it with Attention
 " seem'd to move in about half a Minute or less, about
 " the Length of 20° , and to go out, as I guess'd, about
 " as much above the Horizon. There was left behind
 " it, where it had pass'd, a Track of a cloudy or faint
 " reddish Yellow Colour, such as red-hot iron or glow-
 " ing Coals have, which remained more than a Minute,
 " seem'd to sparkle, and kept its Place without falling.
 " This Track was interrupted, or had a Chasm towards
 " its upper end, at about two Thirds of its Length. I
 " did not hear any Noise it made, but the place where
 " the Globe of Light had been, remain'd after it was
 " extinct, of the same reddish Yellow Colour with the
 " Stream for some time, and at first some sparks seem'd
 " to issue from it, such as come from red-hot Iron bea-
 " ten on an Anvil. The Surprize, Brightness of the
 " Light, and Noise of the People upon the Variations
 " of the Appearance, calling to one another to observe
 " what they never had observ'd in their Days, and
 " thought to be prodigious, hinder'd me from taking
 " notice or remembering any thing farther about it.

It were to be wisht that Sir Hans had more especially regarded the Situation of the Track of this Meteor among the fixt Stars, and let us know how much it past above the Pleiades, and how much under the Belt of Orion, that so we might with more Certainty have determin'd its Position in respect of the Horizon of London; for which purpose the whole Number of Spectators there has not furnished us with one sufficient Observa-

Observation. But all the Relations, however otherwise differing, agree in this, that the Splendour was little inferior to that of the Sun; that within doors the Candles gave no manner of Light, and in the Streets not only all the Stars disappear'd, but the Moon then Nine Days old, and high near the Meridian, the Sky being very clear, was so far effaced as to be scarce seen, at least not to cast a Shade, even where the Beams of the Meteor were intercepted by the Houses: so that for some few Seconds of Time, in all respects it resembled perfect Day.

The Time when this happen'd was generally reckoned at a quarter past Eight; but by the more accurate Account of the Rev. Mr. Pound (who only saw the Light) agreeing with what has been sent us from the *Parisian Observatory*, it appears to have been at 8^h 8' apparent Time at *London*. And the Sun being then in 9½ gr. of *Aries*, the Right Ascension of the Mid-Heaven was 130 gr. 45', whereby the Position of the Sphere of fixt Stars is given. Hence the *Lucida Pleiadum* will be found at that time to have been 25½ gr. high, in an Azimuth 6 gr. to the Northward of the West, and consequently the Arch the Meteor moved in, was inclined to the Horizon with an Angle of about 27 gr. having its Node or Intersection therewith, nearly *South South West*; as will be more evident by what follows.

At *Oxford* five Minutes earlier, Mr. *John Whiteſide*, R. S. Soc. Keeper of the *Ashmole Museum*, and very skilful in both Mathematical and Physical Matters, immediately after the Extinction of the Meteor, made haste out to see what it might be, and well consider'd the Situation of the Track it had left in the Sky: He found it to have past about 1½ Degree above the preceding Shoulder of *Orion*, and about 3½ gr. above

the middle of his *Belt*, where there appear'd a luminous *Nubecula* of a reddish Light, being a Dilatation of the Track, seeming to have been occasion'd by some Explosion there; and by what he could learn from those that saw it, it was thereabout that it broke out, and first began to efface the Stars. Hence it proceeded as to sense in an Arch of a great Circle, and passing in the middle between the Tail of *Lepus* (θ *Bayero*) and β in the Fore-Foot of *Canis major*, it terminated about ξ in the Breast of the same, nearly in 95 gr. of Right-Ascension, with 23 gr. South Declination: and at the place of its Extinction there remained a large whitish *Nebula*, much broader and of a stronger Light than the rest of the Track, which he took for a certain Indication of a very great Explosion made there. By Computation it will be found that the Angle this Track made with the Horizon of *Oxford* was nearest 40 gr. and its Intersection due *SSW*; and that the place of its Extinction was about 9 gr. above the Horizon, in the Azimuth of 32 gr. to the *West*.

At *Worcester* Mr. *Nicolas Fatio*, a Person greatly skill'd in Astronomical Affairs, saw this Meteor descend obliquely towards the *South*, making an Angle with the Horizon of about 65° , and intersecting it about *SSW* $\frac{1}{2}$ *S*, as may be collected from a Scheme thereof sent up by him, and communicated to the *Royal Society*, seeming to be design'd with sufficient Exactness. By this the Track left all *Orion* and *Canis major* to the *Westward*, and divided the Distance between *Sirius* and *Procyon*, so as to be almost twice as far from *Procyon* as *Sirius*. The Time here was one Minute before Eight, this City being about 9' of Time to the West of *London*, and consequently the Right-Ascension of the Mid-Heaven 128 $\frac{1}{2}$ gr.

Now the Situation of the three Cities *London*, *Oxford*, and *Worcester* being nearly on the same *W.N.W.* Point, whereon the Track of the Meteor had its greatest Altitude above the Horizon, equal to the Angle of its visible Way; if we suppose it at *London* to have been 27 gr. high, and at the same time at *Worcester* to be 65 gr. high, in the Plane of the Vertical Circle passing through *London* and *Worcester*; supposing likewise the Distance between them to be 90 Geographical Miles, or one Degree and half of an Arch of a great Circle of the *Earth*, we shall by a Trigonometrical *Calculus*, too obvious to be here inserted, find the perpendicular Height to have been 64 such Miles; and the Point over which it was then perpendicular to have been 30 such Miles *W.N.W.* from *Worcester*. And the Geographical Mile to the *English Statute Mile* being as 23 to 20, this Height will be no less than $73\frac{1}{2}$ *English Miles*. The place also directly under it, will be found to be about *Prestain* on the Confines of *Hereford* and *Radnor-Shires*. Nor can we be much out in this Determination, the *Oxford Observation* concurring nearly in the same Conclusion.

This Altitude being added to the Semidiameter of the *Earth* as *Radius*, becomes the *Secant* of Eleven Degrees, so that the Meteor might be seen above the Horizon in all Places not more than 220 Leagues distant from it. Whence it will not be strange that it should be seen over all Parts of the Islands of *Great Britain* and *Ireland*, over all *Holland* and the hither Parts of *Germany*, *France* and *Spain*, at one and the same instant of Time.

This suggests a very great use that might be made of these momentaneous *Phænomena*, to determine the *Geographical Longitudes* of Places. For if in any two Places two Observers, by help of *Pendulum Clocks* duly corrected

by Celestial Observation, do exactly note at what Hour, Minute and Second such a Meteor as this blows up and is extinguished, the Difference of those Times will be the Difference of Longitude of the two Places, as is well known. Nor does it require so much as the Use of a *Telescope*, as in the Methods hitherto put in practice for that purpose: so that if these Appearances could be predicted, and Notice given of their coming, that we might know when to expect them, I should make no Difficulty to prefer this way of settling the *Geography* of a Country before all others.

Having thus fixt one Point in the Line of its Motion, let us now consider what course the Meteor took from thence. And first at the Town of *Kirkby-Stevens*, on the Borders of *Yorkshire* and *Westmoreland*, in a Meridian very little to the Westward of *Worcester*, but about $2\frac{1}{2}$ gr. more to the North, it was observed to break out as from a dusky Cloud, directly under the Moon, and from thence to descend, nearly in a Perpendicular, almost to the Horizon. Now the Moon, being at that time in the third Degree of *Leo*, was about half an hour past the Meridian, and consequently much about a point to the West, or S b W: and the Situation of *Prestain* from *Kirkby-Stevens* being sufficiently near upon the same Point, it follows that the Direction of the Track of the Meteor was according to the Great Circle passing over those two Places.

And this is further confirm'd by the Observation of *Sam. Cruuys*, Esq; *Reg. Soc. Soc.* who at *Tiverton*, about twelve Geographical Miles nearly due North from *Exeter*, observed the first Explosion of this Meteor exactly in his Zenith, as he was assured by applying his Eye to the side of his Door, which he took to be perpendicular, and looking upwards: And from thence he saw it descend to the Southwards directly in the same

Azimuth, without declining either to the Right or Left: Hence it is plain, that the Track likewise pass'd over this place, which by our best Maps is found to lie in a Line with *Prestain* and *Kirby-Stevens* with sufficient Exactness; so that we shall take it for granted that this was the very Course it held.

On this Supposition, that the first Explosion attended with the reddish *Nubecula*, was directly over *Tiverton*, we have the *Oxford* Observation to compare with it, in order to determine more nicely the perpendicular Altitude there. At *Oxford* this *Nubecula* was found to be $3\frac{1}{2}$ gr. above the middle Star of *Orion's Girdle*, at $8^{\text{h}} 3'$, and was therefore $26\frac{1}{2}$ gr. above the Horizon; and the Distance between *Oxford* and *Tiverton*, being $1^{\circ} 55'$ or 115 Geographical Miles, it will be as the Sine of $61^{\circ} 35'$ to the Sine of $63^{\circ} 30'$ So the Semidiameter of the Earth being $3437\frac{1}{2}$ such Miles, to 3498 Miles the Distance of the Meteor from the Center of the Earth; from which deducting the Semidiameter, there remains $60\frac{1}{4}$ Geographical Miles for the Height of the Meteor above *Tiverton*: And that this was so is confirmed by the Observation of the Rev. Mr. *Will. Derham*, who at *Windsor* saw the aforesaid *Nubecula* about two Degrees above the most Southerly of the Seven Stars in the Shield of *Orion*; that is (the Time being $8^{\text{h}} 6'$) in the Altitude of $23\frac{1}{2}$ gr. whence, the Distance between *Tiverton* and *Windsor* being 150 measured Miles, or 130 Geographical, by a like Proportion we shall find the same Height of the Meteor 60 such Miles wanting only one Quarter. So that in a round Number we may conclude it to have been just 60 Geographic or 69 Statute Miles above the Earth's Surface. Nor is it possible to come at a precise Determination of this matter, by reason of the Coarseness and Inaccuracy of our *Data*, which were only

only the Notes of Persons under the Surprize of the suddenness of the Light, and no ways pretending to Exactness; however, such as they are, they abundantly evince the Height thereof to have exceeded 60 English Miles, not to say 38 or 40, as some would fain have it.

I was unwilling to leave off, till I had pitcht upon some Hypothesis that might subject the Motion of this Meteor to a *Calculus*, that the Curious might be able to compute the visible way thereof, either in respect of the Horizon, or among the fixt Stars: This I found might be done with tolerable Exactness, supposing that it mov'd in the Arch of a Circle concentrick with the Earth, but 60 Geogr. Miles without it; and that the Point of the first Explosion was over the Lat. of $50^{\circ} 40'$ and $3^{\circ} 40'$ to the West of *London*; and that of the last Extinction over Lat. $47^{\circ} 40'$ with $4^{\circ} 50'$ West Longitude: The Time being fixt to 8 Minutes past Eight at *London*. Hence it will be easy, by a Trigonometrical Process, to obtain the visible Altitude and Azimuth of the Meteor at either of its Explosions, as seen from any Place whose Longitude and Latitude is known; and from the Time given, the Points in the Sphere of Stars answering to those Azimuths and Altitudes are readily deduced. Let those that contend for a much less Height of this Meteor try if they can on such their Supposition reconcile the several *Phænomena* before recited with one another, and with the Observation of the Rev. Mr. *William Ella*, Rector of *Kampton* in *Nottinghamshire*, between *Gainsborough* and *Redford*, which for its Exactness I must not omit. Here at $8^{\text{h}} 5'$ the Meteor was seen to pass precisely in the middle between *Sirius* and the Fore-Foot of *Canis major*, moving obliquely to the Southward, in a Line whose Direction seem'd to be from the middle between

the two Shoulders of Orion. The Latitude of the place being nearly $5^{\circ} 20'$, and Longitude *West* from London $0^{\circ} 45'$. Let them try how they can account for its being seen five Degrees high at Aberdeen in Scotland, and near as much at Peterhead half a Degree more Northerly : and then they will be better able to judge whether it did not exceed the reputed Limits of our Atmosphere. Lastly, if the apparent Altitude of the Meteor at Paris was not $5\frac{1}{2}$ but $11 gr.$ on the *Wb N* Point, when it must have been in its greatest Lustre, there will be no pretence to bring it lower than I have made it, especially if it be allowed to have follow'd the Track I have assign'd it, over Prestain, Cardiff, Minhead, Tiverton, and Brest in Bretany.

Allowing this to have been the Path it mov'd in, it would be easy to assign the real Magnitude and Velocity of this Meteor, if the several Accounts of its apparent Diameter, and of the Time of its Passage from one of its Explosions to the other, were consistent with themselves. But some of them making its visible Appearance nearly equal to the Sun's, which in the Opinion of many it far exceeded, we may suppose with the least that, at the time when it first broke out over Tiverton, its Diameter was half a Degree. And its Horizontal Distance being 150 Geogr. Miles from London, and its Altitude 60, the Hypothenusal or real Distance from the Eye will be more than 160 such Miles ; to which Radius the Subtense of half a Degree will be above an English Mile and half, being about 2800 Yards quamproximè. After the same manner it is difficult to assign its due Velocity, whilst some make it half, others less than a quarter, of a Minute, in passing from its first Explosion to its last Extinction : But the Distance it moved in that time being about 3 gr. or 180 Geogr. Miles, we may modestly compute

it to have run above 300 such Miles in a Minute ; which is a Swiftness wholly incredible, and such, that if a heavy Body were projected horizontally with the same, it would not descend by its Gravity to the Earth, but would rather fly off, and move round its Center in a perpetual Orb, resembling that of the *Moon*.

Of several Accidents that were reported to have attended its Passage, many were the effect of pure Fancy ; such as the hearing it hiss as it went along, as if it had been very near at hand : others imagined they felt the Warmth of its Beams ; and some there were that thought, at least wrote, that they were scalded by it. But what is certain, and no way to be disputed, is the wonderful Noise that follow'd its Explosion. All Accounts from *Devon* and *Cornwall* and the neighbouring Counties are unanimous, that there was heard there, as it were the Report of a very great Cannon, or rather of a Broad side, at some distance, which was soon follow'd by a rattling Noise, as if many small-Arms had been promiscuously discharged. What was peculiar to this Sound was, that it was attended with an uncommon Tremour of the Air, and every where in those Counties, very sensibly shook the Glass-Windows and Doors in the Houses, and according to some, even the Houses themselves, beyond the usual Effect of Cannon, though near ; and Mr. *Crurys* at *Tiverton*, on this occasion, lost a Looking-Glass, that being loose in its Frame, fell out on the shock, and was broken. Nor do we yet know the Extent of this prodigious Sound, which was heard, against the then Easterly Wind, in the Neighbourhood of *London*, as I am inform'd ; and by the Learned Dr. *Tabor*, who distinctly heard it beyond *Lewis* in *Sussex* : So that I cannot help thinking, that such a Meteor as this might have occasion'd that famous Ode of *Horace* : *Parcus Deorum cultor, &c.*

— Namque Diespiter

Igne corusco nubila dividens

Plerumque, per purum tonantes

Egit equos volucremque currum,

Quo bruta tellus, &c. Concuditur. —

But whether the Report heard near *Levis* were of that Explosion right over *Devonshire*, or rather of that latter and much greater at the Extinction over *Britany*, I shall not undertake to determine, till we have some further Accounts from *France*, whence hitherto we have only had, that at *Paris* the Time of the Appearance was at 17 Minutes past Eight.

It remains to attempt something towards a Solution of the uncommon *Phenomena* of this Meteor; and by comparing them with things more familiar to us, to shew at least how they might possibly be effected. And first the unusual and continu'd Heats of the last Summer in these Parts of the World, may well be suppos'd to have excited an extraordinary Quantity of Vapour of all sorts; of which the aqueous and most others, soon condens'd by Cold, and wanting a certain Degree of Specifick Gravity in the Air to buoy them up, ascend but to a small Height, and are quickly returned in Rain, Dews, &c. whereas the inflammable sulphureous Vapours, by an innate Levity, have a sort of *Vis centrifuga*, and not only have no need of the Air to support them, but being agitated by Heat, will ascend in *Vacuo Boileano*, and sublime to the top of the Receiver, when most other Fumes fall instantly down, and lie like Water at the bottom; the Experiment whereof was first shewn me by the Reverend Mr. *Whitefide* at *Oxford*, and was very lately made before the *Royal Society*. By this we may comprehend how the matter of the Meteor might have been raised from a large Tract of the Earth's Surface, and ascend far above the reputed Limits of the *Atmosphere*; where, being disengaged from all other Particles, by that principle of Nature that congregates *Homogenia* visible in so many Instances, its Atoms

Atoms might in length of time coalesce and run * *fortuitously* together, as we see Salts shoot in Water; and gradually contracting themselves into a narrower compass, might lie like a Train of *Gunpowder* in the *Ether*, till catching fire by some internal ferment, as we find the Damps in Mines frequently do, the Flame would be communicated to its continued parts, and so run on like a Train fir'd.

This may explain how it came to move with so unconceivable a Velocity; for if a continu'd Train of Powder were no bigger than a Barrel, it is not easy to say how very fast the Fire would fly alongst it; much less can we imagin the Rapidity of the Accension of these more inflammable Vapours, lying in a Train of so vast a Thickness. If this were the Case, as it is highly probable, it was not a Globe of Fire that ran along, but a successive kindling of new Matter: and as some parts of the Earth might emit these Vapours more copioufly than others, this Train might in some parts thereof, be much denser and bigger than in others, which might occasion several smaller Explosions, as the Fire ran along it, besides the great ones which were like the blowing up of Magazines. Thus we may account for the rattling Noise like small-Arms, heard after the great Bounce on the Explosion over *Tiverton*; the Continuance of which for some time, argues that the Sound thereof came from Distances that encreased.

What may be said to the Propagation of the Sound thro' a *Medium*, according to the receiv'd Theory of the Air above 300000 times rarer than what we breath, and as I said before, next to a *Vacuum*, I must confess I know not. Hitherto we have concluded the Air to be the Vehicle of Sound; and in our artificial *Vacuum* we find it greatly diminish'd: but we have this only Instance of the effect of an Explosion of a Mile or two diameter, the immensity of which may perhaps compensate the extream Fineness of the *Medium*.

F I N I S.

* Dele *fortuitously*.